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How green is greening? A fine-scale analysis of spatio-temporal dynamics in Germany

Tobia Lakes [*,a,b]; Jaime Garcia-Marquez [a]; Daniel Müller [a,b,c]; Sebastian Lakner [d]; Guy Pe'er [e,f,g]

January 2020

Abstract

The "Greening" measures of the EU's CAP, implemented in 2015, have been intensively debated in terms of their effectiveness and efficiency for agricultural, environmental, and climate outcomes. This study explores the fine-scale spatiotemporal dynamics of Ecological Focus Areas (EFAs) (with a particular emphasis on fallow land). We use annual land-use data at the plot level from IACS for Brandenburg in Germany from 2005 to 2018 and apply quantitative spatial metrics. In result, we find EFA measures to represent a small percentage of the total area of agriculture, with catch crops dominating, followed by fallow land and nitrogen-fixing crops. Fallow land decreased until 2015 and slightly increased with the introduction of Greening. Half of the fallow land in 2015 was fallow land in the previous year, while the other half had been used for cereals, fodder and oil seed plants. A large share of fallow land shows a low permanency of 1 up to 4 years. EFAs and particularly fallow land hence may contribute to environmental performance in agricultural land use, yet currently they do so to a limited degree. We suggest a change in types of EFA measures, spatial optimisation to reduce fragmented patterns, and a higher permanency of fallow land by a better alignment of agricultural and landscape policies and planning.

Keywords: sustainable land use, common agricultural policy, ecological focus areas, fallow land, Integrated Administration and Control System (IACS)

JEL codes: Q570, Q1, Q580

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1 Introduction

Agricultural production provides increasing amounts of food, feed, and fibre but also causes major environmental externalities, such as greenhouse gas emissions (EC 2018, Pe'er et al. 2019), biodiversity decline (Díaz *et al.*, 2019; Seibold *et al.*, 2019), soil erosion (Orgiazzi *et al.*, 2016) and excessive nutrient loadings (Kotiaho and Halme, 2018). In particular, the intensification of agricultural production is considered a main culprit for biodiversity decline, the deterioration of pollination services, and a reduction in ecosystem services (Ottoy *et al.*, 2018; Díaz *et al.*, 2019; IPBES, 2019). Thus, policy interventions that aim to address some of the externalities of agricultural land use have gained increasing popularity in the political communication, despite that budgets for environmental interventions have shown to be lagging behind (Erjavec and Erjavec, 2015) and that the effectiveness of these policies remain largely unclear (Kleijn *et al.*, 2011). As a response, the Common Agricultural Policy (CAP) of the European Union (EU) has implemented Greening measures and other policy adaptations in its 2013 reform, aiming to steer land users towards more sustainable practices – either by compensating producers for their investment in delivering public goods (i.e. through expanding Agri-Environmental to Agri-environmental and Climate Measures (AECM)) or by setting stronger environmental requirements for the Direct Payments, by dedicating 30% to the Greening requirements in order to enhance environmental protection beyond Cross Compliance (EC, 2017; Ottoy *et al.*, 2018).

The Greening of Direct Payments in the 2013 CAP reform comprised of introducing three mandatory actions following the approach to link Direct Payments to sustainability criteria: crop diversification, the maintenance of permanent grasslands, and the establishment of Ecological Focus Areas (EFAs) (BMEL, 2015; Thoyer and Préget, 2019). In more detail: (a) crop diversification requires farms with arable land exceeding 20 or 30 hectares to grow at least two or three crops, respectively; (b) maintenance of permanent grasslands, allows a maximum loss of 5% by 2020 (at the national level); and (c) promotion of Ecological Focus Areas (EFAs) on at least 5% of the arable land on farms with more than 15 ha of conventional arable land. Here we concentrate on the EFAs as the flagship element of Greening with respect to biodiversity, with the explicit objective "to safeguard and improve biodiversity on farms" (Recital 44 of Regulation (EU) 1307/2013). Beyond biodiversity, EFAs also target co-benefits for soils, ecosystem services, and climate regulation (EC, 2013).

The different options to classify land as EFA include a 'weighting factor' that determines the actual area required to meet the target of 5% of a farm's arable land. For example, a weighting factor of 0.3 for catch crops means that farmers need to register at least 16.7 ha of catch crops out of 100 ha to meet the target of 5 ha EFA (16.7 ha * 0.3 = 5.0 ha). The weighting factor for fallow land is 1, so 5 ha of fallow land equal 5 ha of EFA. Nitrogen-fixing crops have a weighting factor of 0.3, buffer strips of 1.5, and landscape elements of 1 (EC, 2013; BMEL, 2015). In consequence, much of the area allocated to EFA has a comparatively low ecological score per ha (nitrogen-fixing crops, catch crops), while interventions that affect only small areas (buffer strips, landscape elements) receive high weighting factors due to their assumed high ecological value. In general every farmer with more than 15 ha cropland has to allocate farmland to EFA, except organic farms, farms that participate in the 'small farmers scheme', and farms that use >75% of their farmland for fodder production, grassland, fallow, permanent pastures, and with a remaining arable land below 30 ha (see specific explanations and sectoral exemptions in EC (2013); Pe'er *et al.* (2014); BMEL (2015)).

A recent overall evaluation of the Greening on an EU-wide level showed the aggregate uptake of the EFA (please also note the regional specifications of the member states on EFA) and the distribution across the countries (EU 2017). A higher proportion of arable land was declared in Mediterranean member states (>10%) in comparison to North Western Europe (<8%) (EC, 2017). This may indicate that farmers with low land use intensity can meet the EFA requirements more easily (Gocht *et al.*, 2017). For Germany, Pe'er *et al.* (2017b) found on an aggregated level that EFA choices supporting the agricultural productivity of soils were on average very prominent, with **catch crops, green cover,** and **nitrogen-fixing crops** dominating, but they also highlighted the large variation in the share of EFA options between the various federal states. The spatial distribution of Greening measures on an aggregated regional level has only recently been analysed in a number of studies (Pe'er *et al.*, 2014; Gocht *et al.*, 2017; Lakner *et al.*, 2017; Pe'er *et al.*, 2017b; Röder *et al.*, 2018; Brown *et al.*, 2019).

The reasons that farmers report for their choices in EFA have been identified by a recent European-wide report (EC, 2017) and by studies that include interviews with farmers and stakeholders in Germany (Nitsch, 2016; Zinngrebe *et al.*, 2017; Schüler *et al.*, 2018). Among the most important factors influencing farmers' decisions was the existing management of the farm areas and the integration into the farm management process, or as stated in the EC report (EC, 2017): “Minimising the risk of non-compliance while avoiding administrative complexity and burden”. For German farmers, second important was the possibility of establishing fallow land on marginal land. Thirdly, EFA measures that form part of the regular crop cycle were mentioned. Fourthly, farmers reported the contribution to nature/environmental conservation as well as the preservation of the land quality by using fallow land. In the report by the European Commission (EC, 2017), environmental considerations were reported to often come last in the order of priority of interviewed farmers. In line with this, other studies also highlighted that most management schemes were already implemented by farmers and then afterwards registered as EFA, and that new incentives are hardly given by the current scheme (Zinngrebe *et al.*, 2017; Schüler *et al.*, 2018).

Unfortunately, Greening has not been accompanied with measures that monitor their impact and efficiency in achieving its stipulated goals (Concepción and Díaz, 2019). Hence one can only rely on earlier studies about the environmental effects of different agricultural land uses. Nitsch (2016) identifies fallow land, flower pastures and buffer strips as most important and positively associated with a higher diversity of flora and fauna compared to cropland. Pywell *et al.* (2015) show in their experiment that agricultural extensification of arable land with fallow land and buffer strips is possible while maintaining or even increasing crop yields. A recent study integrated the views of ecologists and farmers into the analysis of impacts of the Greening on biodiversity and identified fallow land as the most important win-win option (Pe'er *et al.*, 2017b). Also a report from the European Commission (EC, 2017) highlighted the importance of fallow land among EFA types as having the greatest net positive environmental and climate impact.

Fallow land, as defined in the Greening regulations, is “arable land not under rotation that is set at rest for a period of time ranging from one to five years before it is cultivated again, or land usually under permanent crops, meadows or pastures, which is not being used for that purpose for a period of at least one year. Arable land which is normally used for the cultivation of temporary crops but which is temporarily used for grazing is included" (EEA, 2019). How to manage fallow land according to EFA is well-defined (Nitsch, 2016). In general, a distinction has to be made between fallow land that is declared as EFA and "normal" fallow land on arable land without the EFA status. After the fifth year, fallow land categorised as "arable land", which is not declared EFA fallow land, will shift into the land use category of permanent pasture (EEA, 2019). In contrast, the EFA status, which must be applied for every year, interrupts the change of main land use from arable land to permanent pasture.

The benefits of fallow land for ecology and biodiversity are mainly due to the lacking or low management intensity that offer possibilities for succession and species recolonization in the agricultural landscape. Modest positive effects of fallow land on biodiversity have been observed by several species-specific studies. For example, low-intensity grasslands increased species richness of birds, while fallow land increased bird species' diversity (Ekroos *et al.*, 2019). Henderson *et al.* (2000) also find positive short-term effects of fallow land on numbers and productivity of birds compared to neighboring cropland. A recent study on habitat use of farmland birds in Germany demonstrated by means of bird counts that fallow land, field strips and landscape elements were supportive, whereas other Greening measures did not show a positive effect on bird abundance (Dellwisch *et al.*, 2019). Additionally, the benefits of fallow land for species seem to depend on the length of the fallow period: small mammals benefited e.g. from longer fallow land periods while plant species with associated rare insect consumers benefited already from arable weed communities in the first two years of succession (Tscharntke *et al.*, 2011). The positive effect of fallow land on biodiversity varies with the size, shape, and location of the plots, and with the position in the landscape in relation to other fallow plots (Tscharntke *et al.*, 2011; Nitsch, 2016). Landscape scale variables, such as connectivity, have been identified as important factors for promoting biodiversity (Brudvig *et al.*, 2009; Concepción and Díaz, 2019). At the same time, setting land aside as fallow has a positive effect on soil quality, reduced soil erosion, and improved water quality and availability (Nitsch, 2016; Orgiazzi *et al.*, 2016). Moreover, fallow land contributes to a more heterogeneous landscape and hence improves landscape aesthetics with benefits for tourism and recreation (Nitsch, 2016), which is another motivation for the establishment of EFAs (Zinngrebe *et al.*, 2017). Fallow land has thus been highlighted in EFA assessments as providing the best outcomes for both farmers and biodiversity (Pe'er *et al.*, 2017b).

While several studies stress the need for evaluating the efficiency and effectiveness of the EFA scheme — and fallow land in particular — on biodiversity (Tscharntke *et al.*, 2011; Oppermann, 2015; Pe'er *et al.*, 2017b; Concepción and Díaz, 2019; Ekroos *et al.*, 2019), to the best of our knowledge, an analysis of spatio-temporal dynamics of EFA-related land-use changes at the level of agricultural plots has been lacking to date. At the same time, both the Green Infrastructure strategy (EC, 2018) and a range of ecological studies repeatedly highlight the importance of improving spatial (and spatiotemporal) optimisation of agri-ecological investments to achieve landscape-level benefits such as increased connectivity and the establishment of larger contiguous habitats (Merckx *et al.*, 2009; Hodge, 2013; Batáry *et al.*, 2015; Lakner *et al.*, 2019). However, only two member states, the Netherlands and Poland, have chosen to implement collaborative implementation of EFAs (Hart, 2015). Assessing the spatial configuration and spatiotemporal dynamics of EFA measures necessitates data and analyses at fine spatial and temporal scales (Lakner *et al.*, 2019). Spatial insights at plot-level promise to reveal the detailed spatial distribution of the establishment of EFAs (Röder *et al.*, 2018) and thus may allow for possible improvements, which are particularly important for the current discussion of the post-2020 CAP reform (Lomba *et al.*, 2017; Pe'er *et al.*, 2019b; Thoyer and Préget, 2019). Data from the Integrated Administration and Control System (IACS) provide annual plot-based land-use information that accompanies the direct payment schemes of the EU CAP. The IACS data hence seem ideally suited to assessing EFA establishments and outcomes (EC, 2017). With the increasing availability of these datasets for research and public use, the insights of this study on data analysis and developed metrics may be of major benefit for studies in other European countries.

Our main objective is hence to evaluate the fine-scale spatiotemporal dynamics of the establishment of EFAs under the CAP Greening. We examine the federal state of Brandenburg in Germany and focus in our analyses on fallow lands, as these are expected to exhibit most positive effects for biodiversity and promise a win-win outcome for biodiversity and farmers. More specifically, our research questions are:

- What is the spatial extent of the established EFA measures and what were the land uses that have been replaced?
- What are the spatio-temporal dynamics of the increase of fallow lands as one key EFA measure and how permanent are the fallow lands?

Based on the outcomes of our analysis, we derive recommendations for the next implementation of the CAP, taking into consideration the current reform process in which Greening is being transformed into a new “Green Architecture” (EC, 2018).

2 Material and methods

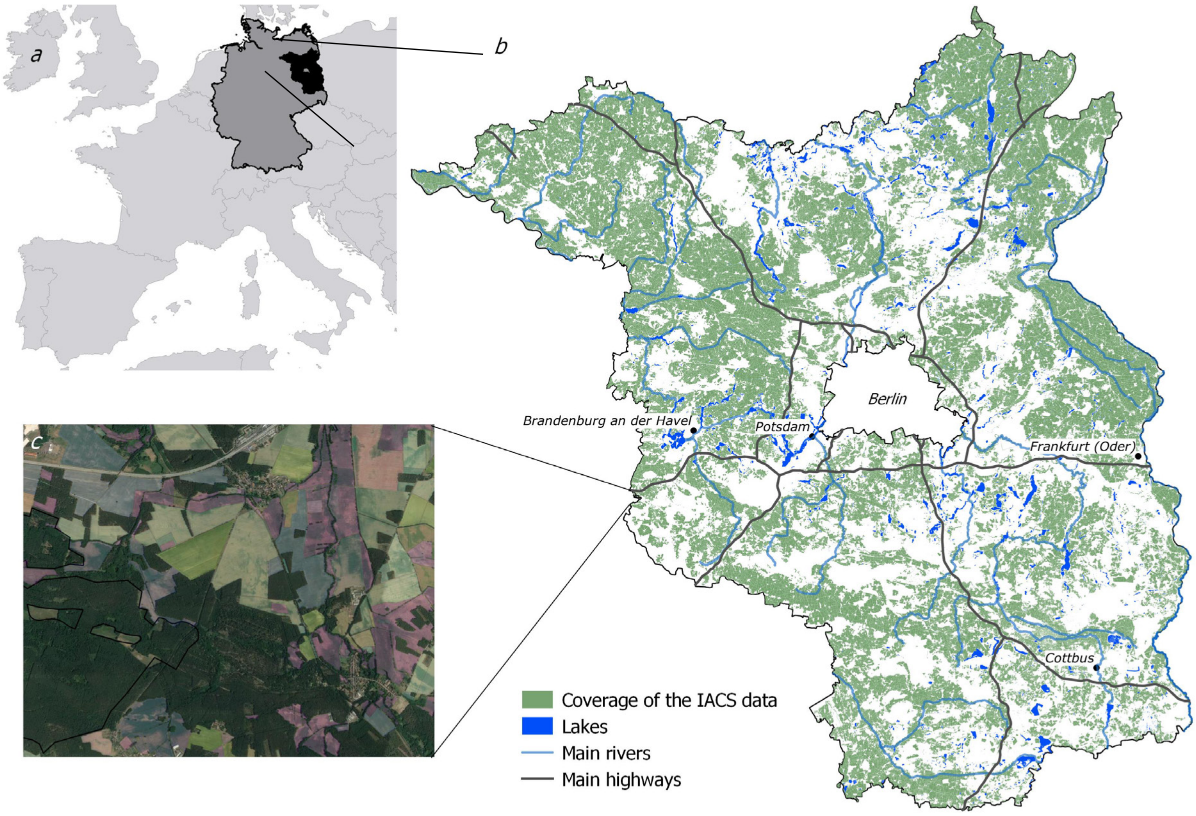
2.1 Study Area

We study the federal state of Brandenburg surrounding Berlin with a total area of 29,640 km². Administratively, Brandenburg is divided into 14 counties and 4 county-level cities, which themselves are subdivided into 2370 sub-districts (“Gemarkungen”). Approximately 45% of the area in Brandenburg is used for agriculture (Figure 1). Since 2000, the size of the agricultural area has remained largely constant. Most of the agricultural land in Brandenburg is arable land (~75%). Soil quality is on average low with almost two-thirds being sandy and sandy-loamy soils (Gutzler *et al.*, 2015). Brandenburg has a warm humid continental climate according to the Köppen classification (Kottek *et al.*, 2006). The average rainfall is comparably low at only 591 mm/year. Rye is the main crop in the area since it is the most suitable for the low soil and long drought conditions, followed by wheat, corn and rapeseed (MIL, 2012).

As in all East-German federal states, agricultural practice is dominated by large farm enterprises in Brandenburg with an average size of 238 ha, which is four times the German average (Gutzler *et al.*, 2015). This condition is partly a legacy of the former socialist times (Batáry *et al.*, 2017), but also fostered by the unfavourable climate and soil conditions (Venghaus and Acosta, 2018). Besides agricultural land use, 8.0% of the area within the federal state of Brandenburg are dedicated as conservation area with important effects for biodiversity and in particular bird biodiversity (Berlin-Brandenburg, 2017).

To sum up, Brandenburg makes a particularly interesting case from an agro-economic perspective because yield levels and therefore the specific value added on many farms in Brandenburg is comparatively low, thus any conservation measure (such as due to Greening) has low opportunity costs. In addition, the dominance of large farms is in general expected to follow a more diverse implementation of EFA due to larger land resources and administrative capacities (Röder *et al.*, 2018).

Figure 1: Study Area.
a. Location of Brandenburg in Germany.
b. Distribution of agricultural land from the IACS.
c. Subset illustrating the high level of detail of the IACS data.



2.2 Data

We used data from the Integrated Administration and Control System (IACS) for the federal state of Brandenburg from 2005 to 2018. IACS includes plot-level land-use data from the identification system for farmers and their payment entitlements and farm-level data from the identification and registration system for livestock. According to the Council Regulation (EC) No 73/2009, the Land Plot Information System (LPIS) must be used by farmers to localize and quantify agricultural land eligible for EU support for the purposes of both farmers' applications and the supervision by government authorities. LPIS is implemented differently across and within EU member states (Sagris *et al.*, 2013) and its underlying data assessment, management and visualisation have also changed over the last years.

In the case of Brandenburg, the baseline map for the registration is a digital cadastre of field blocks that is available since 2015. Until then, plots were digitised manually by farmers with an allowed tolerance of 10% (MELF 2019). The field block cadastre covers all agricultural area in Brandenburg that is eligible for EU subsidies, with location, size and additional information of the field blocks, and is updated based on orthophotos. A field block represents a coherent agricultural area surrounded by permanent borders (such as roads, paths, trees), with predominantly uniform main land use. However, one or more farmers can use a field block so that the area of one field block may be split according to the area of each farmer who applied for subsidies. In addition, the size and outlines of registered plots for subsidies can change over time. In result, the georeferenced land use data that we use refers to those plots for which farmers applied for subsidies. The outlines of the plots are hence mostly aligned with the underlying field blocks but may have been edited by the farmer due to the specific land use in a specific year. Next to the agricultural use on plot-level, landscape elements such as hedges, rows of trees, and single trees, which are located in a field block, are also registered. In Brandenburg, the landscape elements have been registered and located with a single point until 2016 and are now digitized with their spatial outlines (e.g. of groups of trees). The reporting date for the IACS data is May 31 for each year from 2005 until 2018.

The available data includes very detailed information on land use and EFA categories (15 categories) according to the IACS classification and the respective subsidy schemes that are available in Brandenburg. We focused on the following EFA categories: catch crops, buffer strips, nitrogen-fixing crops, fallow land, and landscape elements. In the latter category, we combined hedges, single trees, tree rows, thickets etc.. Fallow land that was reported from farmers before the implementation of EFA in 2015 will be called pre-EFA fallow land in the following. In addition, fallow land, that does not fall into the EFA fallow land scheme, is reported in the IACS data. In addition to the plot-level land use information, the farm identifier of a plot allows us to assess which plot belongs to which farm, so that the size of the farm and the type of farming (conventional versus organic) can be assessed.

2.3 Methods

We undertook several steps of pre-processing the IACS data in preparation for analysis. We homogenised the land-use categories when their labels changed over time (e.g., categories were split into more detailed classes, such as maize into maize for silage and maize for biogas; in other instances, categories were added, such as the EFA measures in 2015). We conducted extensive topologic and geometric corrections particularly for the years 2005 to 2014 when plots were digitised manually by the farmers. With the introduction of the digital field block cadastre the data quality of the georeferenced plots improved, but we still had to account for editions that farmers had made. This reporting system created numerous geometrical errors, such as overlapping fields and duplicate nodes of the plot polygons, particularly for the earlier years. Missing data occurred mainly due to changes in categorical labels that left some years without any attribute values for some categories. We therefore combined the respective categories.

To describe the overall uptake of the EFA measures, we accounted for the fact that not every farm has to establish EFA measures and approximated the share of agricultural land at the sub-district level which is eligible for Greening measures (EEA 2019). That means we removed all plots dedicated to organic agriculture and all plots that belong to farms with an area < 15 ha and thus are not eligible for EFA measures. We then aggregated the remaining land-use data to the sub-district level and calculated for each sub-district the total area and the share of each type of EFA, the number of plots, as well as the mean, median, minimum, and maximum size of plots. Next, we intersected all plots from pairs of consecutive years starting the year before the introduction of the EFA scheme (i.e. 2014 and 2015 until 2017 to 2018) to examine the agricultural use that was replaced by an EFA measure. We then calculated transition matrices to quantify the area and the percentage of losses and gains for the different land uses as a result of the establishment of EFAs and visualised those. To map the different farm sizes in Brandenburg we dissolved the plots for the farms using the primary key for a farm unit from the IACS data. We received 6,040 farms with an average size of 220 hectares. We then intersected the farm sizes with the subdistricts to assess an average farm size per subdistrict. Since the plots of large farms are spreading over several districts the average values are higher (550 hectares). Nonetheless, the resulting map allows to depict the spatially explicit distribution of different farm sizes across the subdistricts.

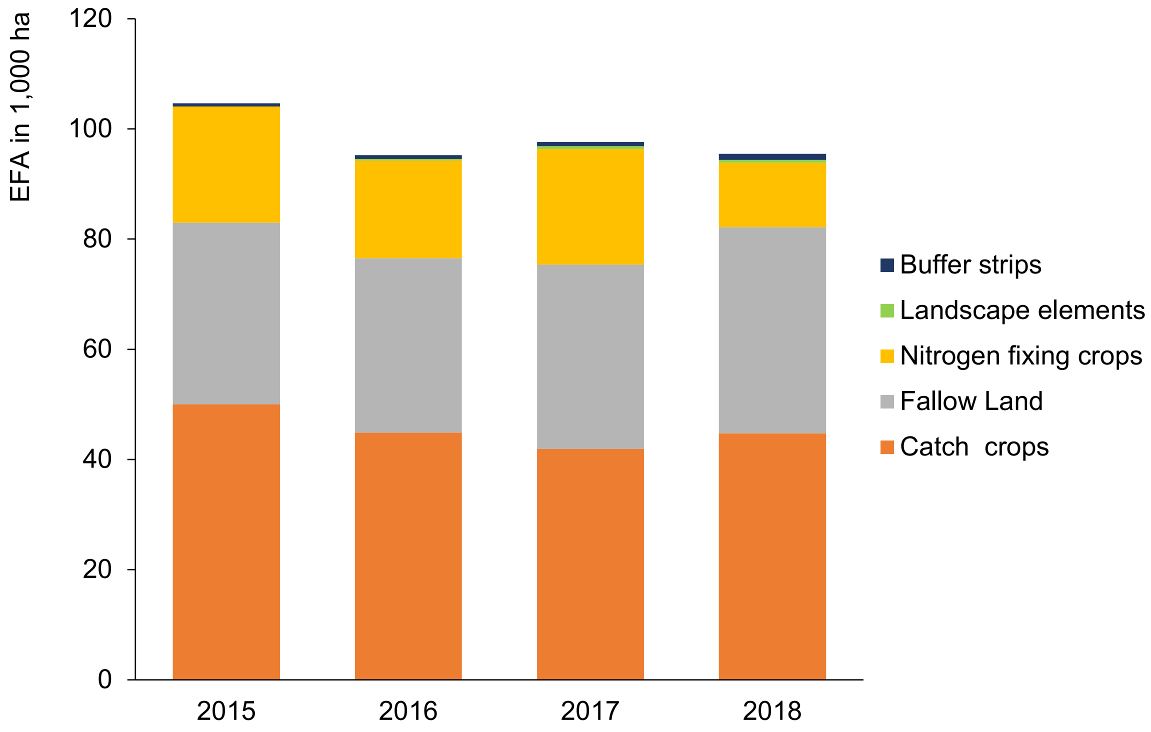
To analyse the fine-scale spatiotemporal dynamics of fallow land, we summed up the area categorised as fallow for each year since 2005. To do so, we converted the plot-based information provided as polygons into binary raster cells with a resolution of 100x100 meters (1 ha). If a raster cell contained more than 50% of fallow land, we labelled it as fallow (=1), otherwise it was labelled with 0. The conversion towards grid cells was necessary to allow for comparisons of plots over time because plot boundaries can change from year to year. The final grid for Brandenburg consists of 2,470 rows and 2,360 columns, resulting in a total of 5,829,200 grid cells. For the years up to 2014 (pre-EFA) we included all fallow land categories. To capture the effect of the EFA measures we analysed only those cells that were registered as fallow in the EFA scheme since 2015. We then calculated the number of years that fallow land remained fallow. For all analyses, we avoided calculating the EFA weighting factors to be able to represent the actual land area.

3 Results

3.1 Spatial patterns of EFAs

On average, EFA were established on about 8% of the agricultural area reported in IACS between 2015 and 2018. From the five EFA measures implemented, catch crops occupied the largest share (on average 46% of the EFA), followed by fallow land (30%), and nitrogen-fixing crops (19%) (Figure 2). Landscape elements and buffer strips cover only very small areas (Figure 2). The total area of EFA measures has fluctuated and decreased slightly from 8.5% in 2015 to 7.9% in 2018. Fallow land was the only EFA category that slightly increased, from 30% (32,955 ha) in 2015 to 37% (37,416 ha) in 2018 (Figure 2).

Figure 2: Spatial extent of EFA measures in Brandenburg from 2015-2018.

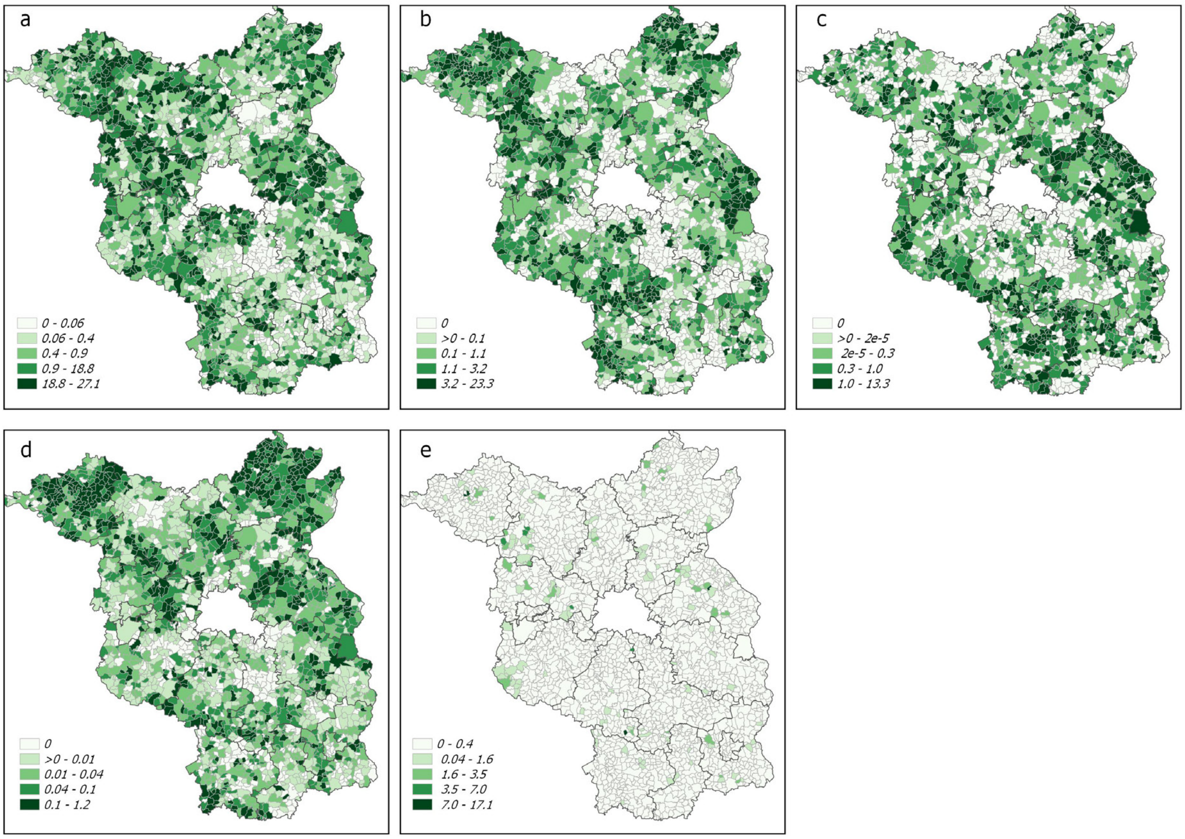


Source: Own calculations;
Note: Area information on buffer strips and landscape elements was only available for 2016-2018)

The EFA measures predominantly occupied small plots. While the number of plots allocated to EFA has increased from 28,472 in 2016 to 38,859 in 2018, the average size of the plots has decreased from 3.5 ha in 2016 to 2.6 hectares in 2018. This is partly due to the inclusion of hedges, single trees, and other small landscape elements that were only recorded in the data as separate plots since 2016. The mean size of the plots varies a lot depending on the type of EFA: catch crops were planted on plots with a mean size of 16 ha over the 4 years (with a maximum size of 233 ha in 2015 and 157 ha in 2018). Plots with nitrogen-fixing crops had a mean size of 10-11 ha in the 4 years with a maximum of 138 ha. In contrast, fallow land showed a constant mean size of 3 ha with very small plots and the maximum plot size varied from 67 ha in 2015 to 100 ha in 2017.

In line with the overall small share of land with EFA measures, the share of EFA area of agricultural land at the subdistrict level was low as well (see Figure 3); the maximum value was 27% of the agricultural area of a subdistrict being fallow (Figure 3a). The specific EFA measures were distributed with a very distinct pattern: While fallow land was fairly evenly distributed across the agricultural areas with a few subdistricts with high percentages of up to 27% (Figure 3a), catch crops tended to be clustered in subdistricts towards the northwest, northeast, the southwest, and the east (Figure 3b). Nitrogen-fixing crops showed a more fragmented pattern and were slightly clustered towards the east; subdistricts with high shares were predominately located in the south of Brandenburg (Figure 3c). Landscape elements had a significantly higher share in the northwest and northeast (Figure 3d) and buffer strips showed a rather fragmented pattern with generally low numbers but a slight dominance towards the west (Figure 3e).

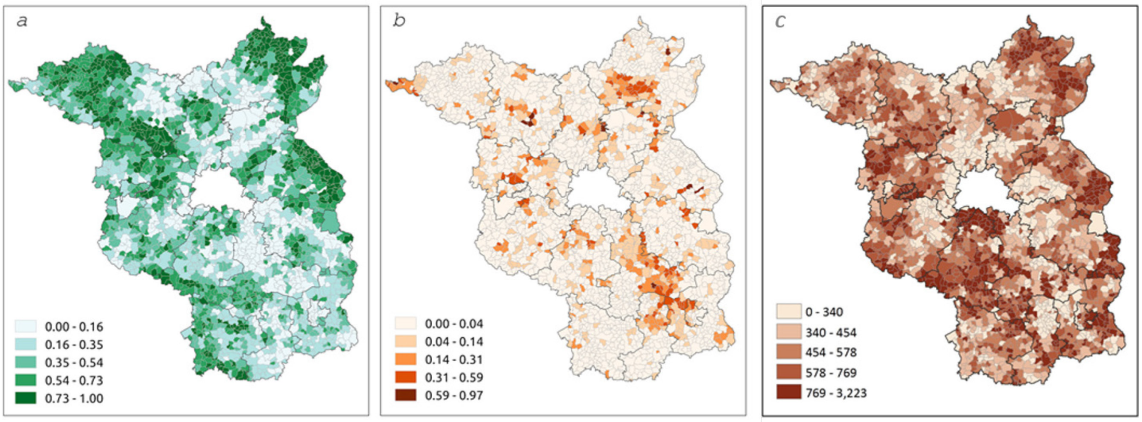
Figure 3: Spatial distribution of EFA measures in Brandenburg.
Average area of the following EFA categories in percent of total area of sub-district (2015-2018):
a. Fallow land;
b. Catch crops;
c. Nitrogen fixing plants;
d. Landscape elements;
e. Buffer strips.



Please note different scales (a-d in quantiles, e in natural breaks). Data source: IACS

Areas with an overall low share of EFA measures coincided with areas where few farms fall into the EFA target scheme (Figure 4a), which in Brandenburg are mainly areas with a large share of organic farms (Figure 4b). Towards the Northeast and East we could identify more areas with nitrogen-fixing crops than compared to the south-eastern parts of Brandenburg. These areas coincided with farmland dominated by large farms (see Figure 4c).

Figure 4: Characterisation of farms:
a. % land of all agricultural land per subdistrict that has to establish EFA,
b. % organic agricultural land of all agricultural land per subdistrict,
c. average size of farm per plot per subdistrict (in ha).



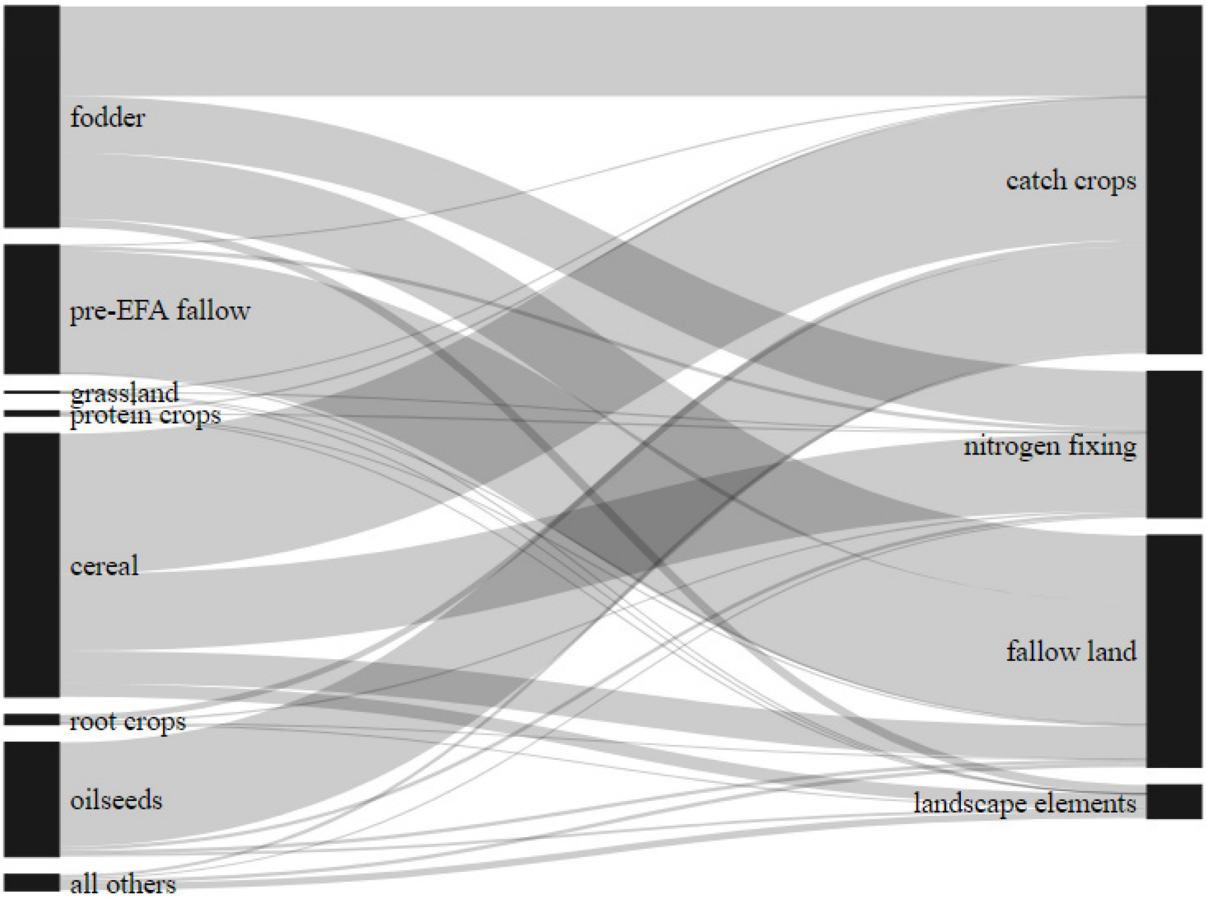
Data source: IACS.

3.2 Land-use transitions in response to the establishment of EFAs

The establishment of EFAs in 2015 reveals contributions from all other main agricultural use types (Figure 5), but mostly from land used for cereals, fodder, and oil seed crops and land that was fallow already before 2015 (fallow pre-EFA).

The largest share of the newly established EFA areas (37,873 ha of the total area of 108,899 ha) were found on land that had been used for cereals in the year before (see Figure 5), Specifically, land for cereals like winter rye and winter wheat transitioned towards catch crops, nitrogen-fixing crops and fallow land. Also, the transformation from land that had been used for fodder (e.g. clover or grass) in 2014 was significant (31,731 ha). Finally, large areas of land that were used for oilseeds and pre-EFA fallow in 2014, were converted into new EFA areas in 2015. For example, 30% of the area of catch crops in 2015 were implemented where previously oil seed plants had been cultivated, particularly sunflowers and winter rapeseed. In the following years the characteristic transitions basically remained similar with cereals, fodder and oil seed plants having been transformed to catch crops and nitrogen-fixing crops and to a smaller degree to fallow land [Supplement 1]. Fallow land according to EFA was established to a large share on land that had been fallow before already (17,589 ha). In fact, this accounted for 53% of the area of the overall EFA fallow land in 2015. In addition, 29% of fallow land was implemented on land that was used for fodder in 2014 (particularly grass fodder, other fodder plants and silage maize) and 14% from cereals (particularly winter rye). The rest of the pre-EFA fallow land showed a transition with the largest shares to fodder or cereals. For the transformation from 2015 to 2016, we observed that 2/3 of the fallow land area remained fallow land (21,376 out of 33,087 ha) (see Supplement 1). The rest of the fallow land from 2014 was predominately used for fodder (2,943 ha) and cereals (5,737 ha) again in 2016. For the following years (2015-2016, 2016-2017 and 2017-2018) the areas of fallow land remained relatively stable, with more than 70% of the fallow area remaining as fallow land in the next years. The other areas rotated with cereals and fodder.

Figure 5: Transition of land uses to EFA areas from 2014 to 2015.



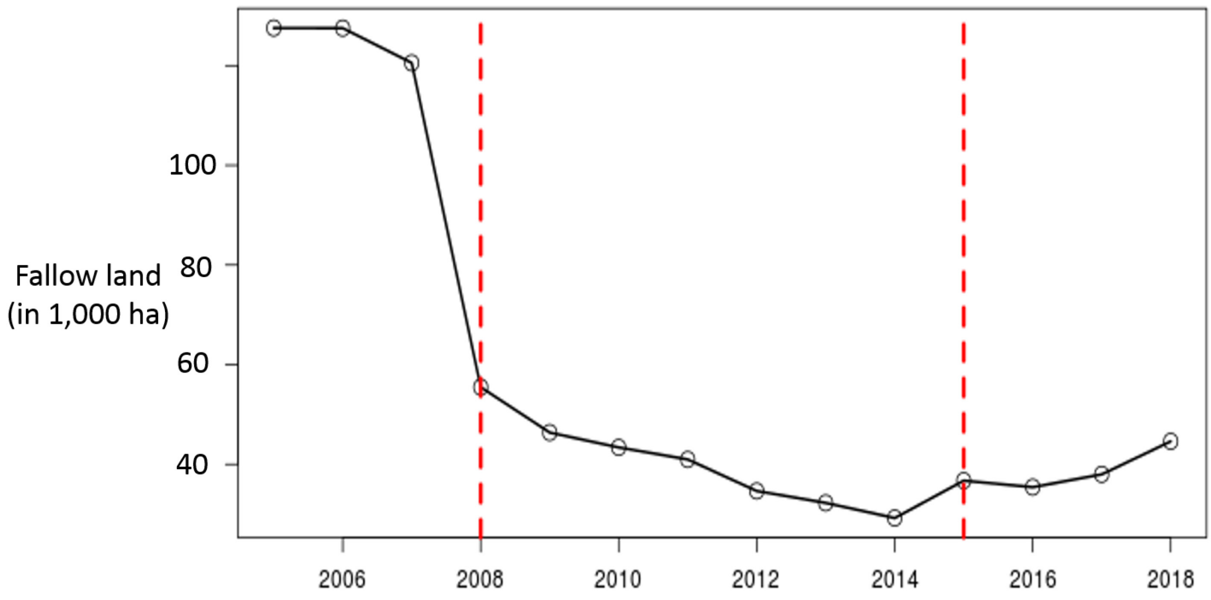
Data source: IACS.

3.3 Long-term trends and permanency of fallow land

Long-term analysis of fallow land shows that there were around 120,545 ha of fallow land in Brandenburg until 2007, which dropped to 5,480 ha in 2008 (Figure 6), a trend that can also be found for whole Germany (Pe’er et al. 2017).

The decrease in the area of fallow land continued, but at lower rates, reaching a minimum of 29,228 ha in 2014. With the implementation of the EFA fallow land category in 2015, fallow land slightly increased to 44,612 ha in 2018, out of which 37,416 ha were EFA-registered fallow land.

Figure 6: Long-term trend of fallow land in Brandenburg.

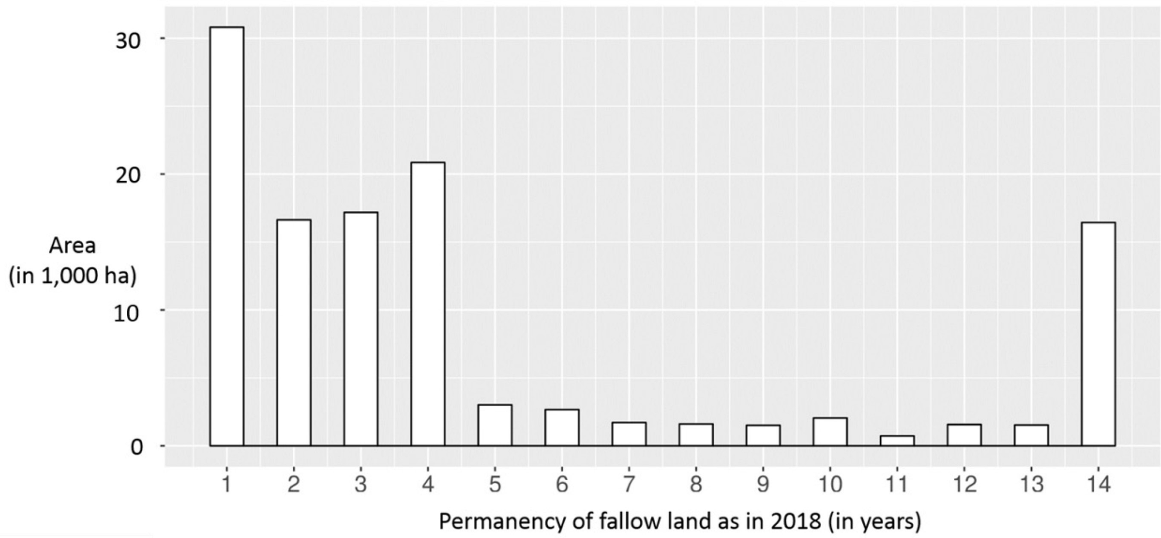


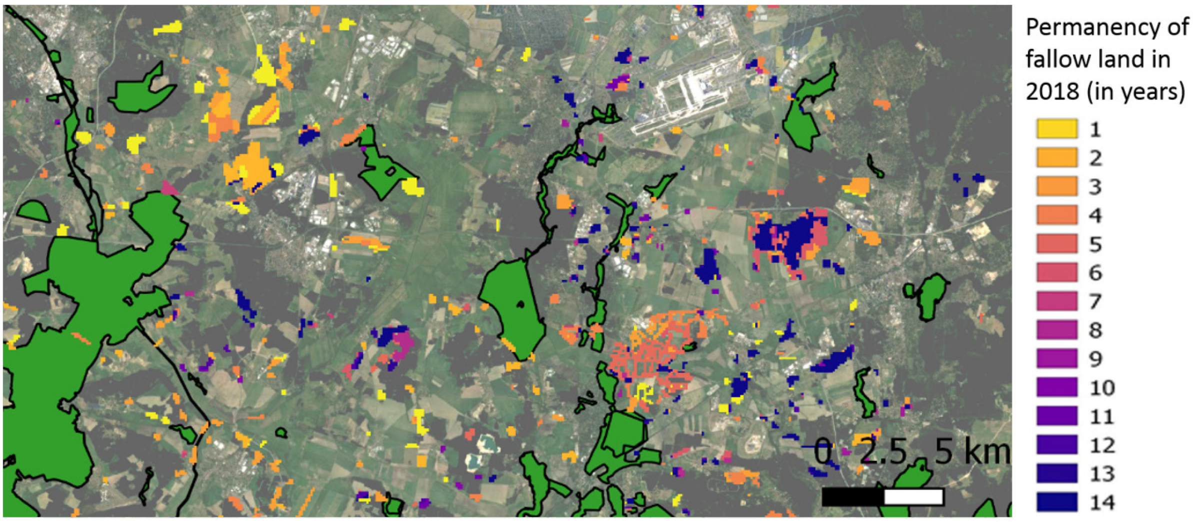
The red dashed line in 2008 represents the year of the phasing out of the compulsory set-aside program and 2015 signals the implementation of Greening. Data source: IACS.

In 2018, most of the area of fallow land still existed with 1 to 4 consecutive years of rotation (i.e. a cumulative number of 87,199 ha) (Figure 7). There is a clear decrease in area in fallow land with a permanency of between 5 years and 13 years. Noteworthy is the area with 14 years of consecutive fallow land, which reflects the whole period of our investigation.

The spatio-temporal dynamics analysis indicates a scattered patterns of distribution of fallow land implementation and duration in the agricultural landscape, with no evident clustering or other organization of short- or long-period implementation.

Figure 7: Permanency of fallow land as in 2018 since 2005,
Top: size of area;
Bottom: example of fine-scaled spatio-temporal patterns with nature conservation areas (NATURA 2000 sites under the European Habitats and Birds Directives).





Data source: IACS. More information at EC (2020): NATURA2000 Viewer. https://ec.europa.eu/environment/nature/natura2000/data/index_en.htm)

4 Discussion

4.1 Implementation of EFA measures: spatial extent, distribution and transitions

In general, all EFA measures that were defined as eligible in Brandenburg were taken up but these only accounted of 8.5% of all agricultural land in 2015, slightly decreasing to 7.9% in 2018. These absolute area numbers (unweighted with respective weighting factors) are in line with other studies that assessed the area of EFA measures for Germany (Lakner *et al.*, 2017; Pe'er *et al.*, 2017b). Taking into account that 5% of conventional agricultural land of farms larger than 15 ha needs to be covered with EFA measures, this accords with a plausible range of the legally required area. In general, compliance with the EFA scheme is reported to be high and avoiding the risk of fines and controlling is driving farmers' decisions on EFA (Lakner *et al.*, 2017; Zinngrebe *et al.*, 2017; Schüler *et al.*, 2018). Risk avoidance might also explain the higher overall share of EFA at the time of implementation of the Greening with a decrease in the following years. Similar to other studies on the uptake of different EFA categories we identify catch crops as most important in terms of area (Zinngrebe et al. 2017; Lakner et al. 2017). In contrast to other regions, however, we see fallow land as the second most important in terms of area and nitrogen-fixing crops coming third in Brandenburg.

Our transition analysis confirms and quantifies what others had argued earlier (Nitsch, 2016; Zinngrebe *et al.*, 2017): Most management schemes were already implemented by farmers and then afterwards registered as EFAs and therefore fail to provide substantial new incentives. In this study, we could show this for catch crops and nitrogen-fixing crops as well as for a large area of fallow land that is included within the crop rotation (see Figure 3 and Figure 4). Particularly since 2017, risk management might play an increasing role in farmer's choice of a specific EFA type, since the summer of 2018 (and also of 2019) was characterised by very high temperatures and low precipitation rates leading to yields below the long year average. Accordingly, farmers have been guaranteed several exceptions in 2018 (and also 2019) to have sufficient fodder for livestock (e.g. use plants grown on fallow land or in buffer strips).

The spatial analysis revealed that the EFA establishment varies substantially in the region for the different categories. The spatial distribution reveals some spatial clusters but mainly a fragmented distribution of different EFA categories across the state that also mirrors the area where organic farming is not dominant. In terms of subdistricts with a large share of larger farms, we see a spatial overlap with large percentages of catch crops. This is somewhat in contrast to Lakner *et al.* (2016) who analyse the IACS data at plot-level for different sizes of farms. They find that especially the larger farms opt for different EFA measures while at the same time allocate a larger share of fallow land, whereas smaller farms rather use one or two EFA-options and prefer productive options such as catch crops. Similarly, we found subdistricts where large farms and large area of fallow overlaps (Lakner *et al.*, 2017). Apart from the farm size the land rent might explain the choice of EFA type, namely, in areas with high value added per hectare of land the more concentrated measures such as buffer strips are found (Lakner *et al.*, 2017). That might also be true for Brandenburg but could not be tested in this study.

4.2 Long-term trends and permanency of fallow land in EFA

Long-term analysis of fallow land shows a similar trend for Brandenburg compared to Germany as a whole (Pe'er *et al.*, 2017b). With the cessation of the set-aside programme in 2008 the area of fallow land dropped significantly in Brandenburg while it increased again with the implementation of Greening (Figure 6). However, it is still very far from the values prior to the abolishment of the set-aside programme in 2008, and, accordingly, much lower than the target of reaching fallow land on at least 10% of the cropland area (Nitsch et al. 2017). Interestingly, 63% of the fallow land in 2014 (17,590 ha) turned into EFA fallow land in 2015, contributing to more than half of the area of overall EFA fallow land in 2015. Regarding the other half of the overall EFA land, our results suggest that fallow land is embedded into the crop rotation cycle, particularly with fodder and cereals. In 2015, we identify, for example, large areas of fallow land under the EFA scheme that that were used as fodder (9,442 ha) and cereals (4,637 ha) in 2014. Again in 2016 we see that fallow land is transitioning to fodder and cereals. Our analysis thus reveals that the 'net-effect' of EFA on area of fallow land is rather limited. Our results thus corroborate those of Nitsch et al. (2017) who suggest that fallow land is included by using fallow areas and as part of the regular rotation cycle (implemented to preserve the land quality) as well as those of the questionnaire-based study criticising EFAs for primarily maintaining existing practices (Zinngrebe *et al.*, 2017).

The uptake of fallow land varies a lot within the Federal State of Brandenburg. While Lakner et al. (2019) stressed that with the establishment of the EFA, fallow land and buffer strips in Lower Saxony were strongly concentrated in protected and marginal areas, in Brandenburg, however, we see a distribution across all areas with several small spatial clusters. We also tested if fallow land was concentrated on marginal soils but did not find any effect in Brandenburg. This might be explained by the generally marginal soils and the poor data on soil quality, which did not allow for a detailed plot level analysis. Nonetheless, larger farms most likely optimise their farm management by establishing fallow lands for example on areas with lower degree of accessibility and lower soil quality. The patterns of permanency reveal an important insight: the largest area of fallow land is only fallow for one year. From the data we cannot derive if that includes fallow in autumn and winter, which would be important in terms of provision of habitats. Nonetheless, the area that remains fallow for 2 to 4 years ranges from approximately 160,000 to 200,000 ha (Figure 6). The rapid decline after year 4 corresponds with the regulation that fallow land would turn into permanent crops, thus corroborating the observations made by Pe'er et al. (2017) and Zinngrebe et al. (2017) that the risk of being "penalized" by this alteration hampers their ecological effectiveness given the positive impacts of longer-term implementation. While there are hardly any areas that are covered by fallow land between 5 to 13 years, we found a large share of area that has been fallow throughout the entire period of investigation (14 years). The permanency of fallow land is, as mentioned above, of high importance for many species and ideally should cover several years (Nitsch et al. 2017).

Our findings suggest that land use following the EFA establishment has not led to a substantial change in land management, and particularly in the use of fallow land. We therefore concur with the experimental design study from Thomas *et al.* (2019) who highlight that "[i]nstead of discussing instrument choice it could thus be more promising to try to reinforce environmental preferences and especially feelings of environmental responsibility" among farmers. We hence argue that perhaps other agri-environmental measures need to be explored that incentivize farmers to adopt more sustainable behaviours. Nitsch et al. (2017) propose, for example, in addition to economic calculations on the farm level (using Greening calculators of agricultural chambers), to adopt more detailed criteria for fallow land, such as upgrading existing landscape elements with neighbouring fallow land or linking fallow land and strips along water bodies so that they are beneficial for biodiversity and the water framework directive. Considering the potential of green infrastructures may be an important asset, e.g. analysing connectivity patterns (Bocedi *et al.*, 2014). Pywell *et al.* (2015) show the positive effect of extensification with buffer areas on yields. Fallow land is also suggested on marginal cropland where productivity losses are lower, or it could be used to separate large plots (Nitsch et al. 2017). A recently developed tool, the EFA calculator, tries to address this need for information and uses a semi-quantitative indicator framework that combines habitat configurations, landscape features, and ecosystem service impacts (Tzilivakis *et al.*, 2016).

These suggestions reveal the high potential if land is not only managed following the business as usual, i.e. merely fitting EFA requirements into existing practices, but rather used to achieve synergies for agriculture and environment across sectors. To this end, spatial planning is needed. Here we highlighted the need for information and guidelines on the plot-level (e.g. soil quality) to know the specific local characteristics but also on the farm-level (e.g. economic considerations) and on the landscape-level (to identify the potential of plots in a larger network of habitats). More comprehensive landscape and spatial planning may be beneficial here. Reaching landscape-scale goals may be difficult, as it would require some coordination between multiple different farms, unless average farms where measures are applied were large enough to influence the landscape structure (Díaz and Concepción, 2016). However, successful examples and experiences can be used, e.g. from the Netherlands (Franks, 2011; Auditors, 2017), including studies demonstrating socio-economic benefits of collaborative implementation (Leventon *et al.*, 2017).

4.3 Policy implications for the CAP post-2020

Our findings need to be placed within the relevant policy context. In the ongoing reform for the CAP post-2020, the European Commission has presented a new Green Architecture which comprises three key elements, namely Agri-Environment-Climate Measures (in Pillar 2), Cross Compliance (CC; an expansion of compulsory measures in Pillar 1) and Eco-Schemes as a voluntary set of measures in Pillar 1 (EC 2018). It was decided not to maintain Greening, instead, some components will move to CC while others could be adopted as Eco-Schemes. Our findings support the idea, also recommended in other studies, that some farm management options should be made compulsory to maintain good agricultural ecological conditions (GAEC) and hence should be moved to CC (e.g. green cover, as means to maintain soil quality, and crop rotation); other measures, that offer a real added value beyond CC, should be separated and rewarded for. However, we note with concern that the vagueness of Eco-Schemes may risk low ambition by member states, e.g. by listing options with low benefits to biodiversity (Pe'er *et al.*, 2019a). Two recommendations emerging from our study are: 1) to clarify the list of options that are entitled to be registered by member states under Eco-Schemes, making effective options compulsory for member states (Pe'er *et al.*, 2017b)); and 2) to ensure that member states not only support fallow land but also offer longer-term implementation e.g. with 7-year contracts. It may be useful to also consider a prolongation of the period until fallow land under Eco-Schemes turn into permanent pastures. Alternatively, the conversion to permanent pastures could be rewarded economically (either through eco-schemes or AECM), to avoid a seeming risk posed by this measure. We also recommend remunerating collective implementation of Eco-Schemes, an option currently not listed in the CAP proposal (Pe'er *et al.*, 2019a). The success of the Swiss scheme, which is based on voluntary measures and reaches over 15% area, may be adopted by the CAP as well (Pe'er *et al.*, 2017a).

4.4 Research implications and methodological considerations

Our presented data analysis can be used for comparative studies elsewhere with the IACS data. In general, the data reveals its large potential for studies of agriculture and environmental effects because of its high spatio-temporal and semantic level of detail. With the ongoing initiatives in the frame of the INSPIRE (Infrastructure for Spatial Information in Europe) Directive and national spatial data infrastructures, synergies for both sides might open up:

existing spatial data and metadata such as ecological data may be used in conjunction with CAP data and CAP data may provide important assets for future analyses of the agricultural landscapes (Tóth and Kučas, 2016). Such data-based developments open up new possibilities for exploring field- and landscape-scale processes by using a set of measures that captures e.g. the permanency of fallow land as suggested here. Calculation of landscape and field configurations towards land use patterns with improved biodiversity outcomes might be a promising next step (Díaz and Concepción, 2016).

We also face some limitations in this study: First, the available data was limited by the topological and semantic changes, by missing data across years and by the fact that the type of land use is only known for one day in the year. In addition, due to changes in plot boundaries we had to undertake the permanency analysis on the grid-level. This might have led to misestimating the area of fallow land. Nonetheless, the data offered very detailed insights on the plot-level for the yearly trend analysis. Second, we did not account for the weighting factors for different categories since we focused on the respective categories in terms of their absolute size, and because fallow land has a weighting factor of 1. Third, we were not able to map the association between EFA categories and environmental or biodiversity outcomes due to missing environmental data. More studies are needed that evaluate the efficiency of measures on species using either field measurements or modelling experiments supported by field work (Concepción and Díaz, 2019; Giacomo Assandri, 2019).

5 Conclusions and outlook

Our findings show the high spatial and temporal dynamics of how EFA categories have been established for the example of Brandenburg, Germany. In particular the large number of areas that seems to remain in the same management scheme and the low permanency of fallow land calls for a revision of the programme. Future work, particularly in the light of current discussions on proposals for CAP post-2020, needs to consider the importance of the environmental settings and outcomes for the subsidies on a plot-, farm- and landscape-level. Future work is crucial for rethinking and aligning agri-environmental funding schemes within the CAP (Lakner *et al.*, 2017). Moreover, we advocate a rethinking of agricultural policies and environmental policies (Hodge *et al.*, 2015), such as objectives of the Water Framework or Sustainable Pesticide Use directives while also achieving the objectives of international agreements, such as the Sustainable Development Goals (Pe'er *et al.*, 2017a; Navarro and López-Bao, 2018; Pe'er *et al.*, 2019a).

A spatially explicit and regional optimisation of EFA establishments might be one important step towards more sustainable agricultural landscapes that truly support the EU's Green Infrastructure. Notably, and regretfully, while the Green Infrastructure strategy acknowledges its dependence on the CAP, the CAP makes no single reference to the Green Infrastructure. The recently introduced policy analysis approach known as "fitness check", which tests policies for their effectiveness, efficiency, (internal/external) coherences, relevance, and European added value (EC, 2015), seems essential in light of a lack of an EU-commissioned assessment of the CAP so far) (Pe'er *et al.*, 2017a). An improved indicator-based framework and tools to support the evaluation of different EFA measures not only for economic but also for environmental reasons on different spatial scales would be an important next step towards a better-informed, results-oriented decision-making as the next CAP proposed to orient itself

(Pe'er *et al.*, 2019a). Finally, we were able to show the benefits and challenges of working with the detailed data available from the IACS for assessing policy-relevant environmental factors (Lomba *et al.*, 2017). These data proved to be an important data source with a large potential for comparative analyses across space and time.

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7 Supplementary Material

Supplement 1: Transition of land use from 2014 to 2015 (top) and 2015 to 2016 (bottom)